

WILD ELEPHANT CENSUS OF KERALA STATE - 2010



Kerala Forests and Wildlife Department
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&
Kerala Forest Research Institute

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WILD ELEPHANT CENSUS OF KERALA STATE - 2010

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PREFACE

Scientific information on the distribution and abundance of wildlife population is a prerequisite for management of wildlife in forests. So far, wildlife censuses based on scientific methods have been carried out in Kerala State during 1993, 1997 and 2002, covering all the major mammal species. In 2005, 2007 and 2010, the population estimation was carried out exclusively for wild elephants following the guidelines of the Directorate of Project Elephant, Ministry of Environment and Forests, Government of India. The Wild Elephant Census was carried out during 15-16 May 2010. This was a coordinated programme conducted concurrently in all the southern States. The whole programme was implemented after a series of discussions among the officials and training programme for the resource persons including participating public.

Every wildlife census is an opportunity to learn more for future corrective measures. The task was quite laborious, but the attempts taken by the scientists and forest officials at all levels to reduce all possible errors are highly appreciated. The census programme was organised and implemented successfully by the officials of Kerala Forest Department and Periyar Foundation and field staff. The team of scientists of Kerala Forest Research Institute conducted the statistical analysis and prepared the report.

I am hopeful that the information generated on elephant population in different Elephant Reserves of Kerala would assist the Kerala Forest Department in the management and conservation and act as a platform for developing a better method for estimating the population of wild elephants.

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EXECUTIVE SUMMARY

Estimation of population of wild elephants was undertaken in all the four Elephant Reserves of Kerala State, using Block Count Method on 15-05-2010 and Line Transect Sampling of Dung on 16-05-2010. The forests were divided into number of small blocks utilizing the maps of the Survey of India. A random sample of blocks, about 50% of total blocks was chosen in each Forest Division for the survey. In the Block Count Method, elephants were counted in the sample blocks and the elephant density (number of elephants per km²) was estimated. The total number of elephants was estimated by multiplying the elephant density with the actual extent of elephant habitat. The direct sighting of elephants further provided information on the population structure.

In the estimation of elephant population based on the Line Transect Sampling of Dung, there were three components involved *viz.*, dung density from Line Transect Sampling, dung decay rate from dung decay experiments and the defecation rate. The elephant density was obtained by multiplying decay rate with the ratio of dung density to defecation rate.

A total of 1911 elephants were sighted in the selected blocks. The estimated wild elephant population in the State by the Block Count Method was 3520 with 95 per cent confidence interval, ranging from 3054 to 3987. The highest elephant density (No./km²) was found in Wayanad Elephant Reserve (0.5798), followed by Anamudi Elephant Reserve (0.5304), Periyar Elephant Reserve (0.4226) and Nilambur Elephant Reserve (0.1799). In terms of total number, Anamudi Elephant Reserve ranked first with 1494 elephants followed by Periyar (1279 elephants), Wayanad (542 elephants) and Nilambur Elephant Reserve (205 elephants).

The age-sex ratio of elephants sighted as, Bull to Cow was Bull to Cow 1:3; Sub-Adult Male to Sub-Adult Female was 1:2 and Adult Cow to Calf was 3:1. Twenty four percent of adult and sub-adult population was tusked.

The estimated elephant population in the State, based on the Dung Survey, was 6026 elephants with 95 per cent confidence interval of 4986 to 7293. This figure is considerably higher than the population estimated from the Block Count Method.

The results of the present census were compared with Elephant Census-2007. The comparison showed an increase in the population from 3002 to 3520. The estimation based on Dung Survey suggests that the elephant population is more or less stable over the years 2007 (6068 elephants) to 2010 (6026 elephants).

1. INTRODUCTION

Information on spatial and temporal trends in the abundance and distribution of elephants in various parts of forests and other demographic characteristics such as age structure, sex ratio, tusker to makhna ratio in adults and the percentage tusked in adult and sub-adult population is essential for effective management and conservation of elephants. Commonly used methods to assess the abundance of wild elephants are Total Count, Block Count, Waterhole Count, Line Transect Sampling and Dung Survey.

Based on the recommendation of the State Wildlife Advisory Board, the Government of Kerala took the policy decision in 1993, to estimate the wildlife population with public participation. The objective was to create a baseline data that would help in monitoring the wildlife population by covering the permanent transects laid for the purpose. Wildlife Census in Kerala was conducted thrice in the past during the years 1993, 1997 and 2002, covering all the large mammals. The methods adopted in the past were

- i. Total Count (Direct sighting)
- ii. Block Count – Sampling (Direct sighting)
- iii. Line Transect Sampling (Direct sighting) and
- iv. Line Transect Sampling (Dung survey)

An overview of these methods is given in Appendix-I.

Unlike the previous wildlife censuses, the census in 2005, 2007 and the present exercise were exclusively for estimating the population of wild elephants as part of All India Census of Wild Elephants. As in earlier censuses, the present census was organized in all the four Elephant Reserves of Kerala following the general guidelines issued by the Project Elephant of the Ministry of Environment and Forests, Government of India.

1.1. Objectives

- a. To learn about trends in population and structure of elephants residing in Elephant Reserves.
- b. To set up accurate baselines for Elephant Reserves, in general, and Monitoring Illegal Killing of Elephant (MIKE) sites, in particular.
- c. To gain information about the status of tuskiers in the Elephant Reserves.
- d. To provide exposure to the field staff regarding sampling techniques useful for enumeration and monitoring of elephants.

1.2. Organization of the Census Programme

The Project Elephant of the Ministry of Environment and Forests has recognized four Elephant Reserves in Kerala vide Order No. G.O (P) No.19/2002/F&WLD. The details of these Elephant Reserves *viz.*, Wayanad, Nilambur, Anamudi and Periyar and their constituent protected areas and territorial forest divisions are provided in Table 1. The map showing different Elephant Reserves is provided in Figure1.

The Elephant Census was organized under the direction and guidance of the Principal Chief Conservator of Forests (Wildlife). The Field Director (Project Tiger, Periyar) was the State Coordinator of the census. The Conservators of the Wildlife Wing were nominated as the Coordinators of the respective Regions.

A one-day training programme was organized for the selected forest officers (resource persons) at different places. The officials were trained on the field techniques to be followed in the census, the method of filling the proforma and care to be taken while collecting the data. The doubts of the resource persons were cleared during the discussions that followed. The method of census and the procedures to be followed in the field for the success of the programme were explained to the field staff in the regional meetings of the forest officers convened by the respective coordinators.

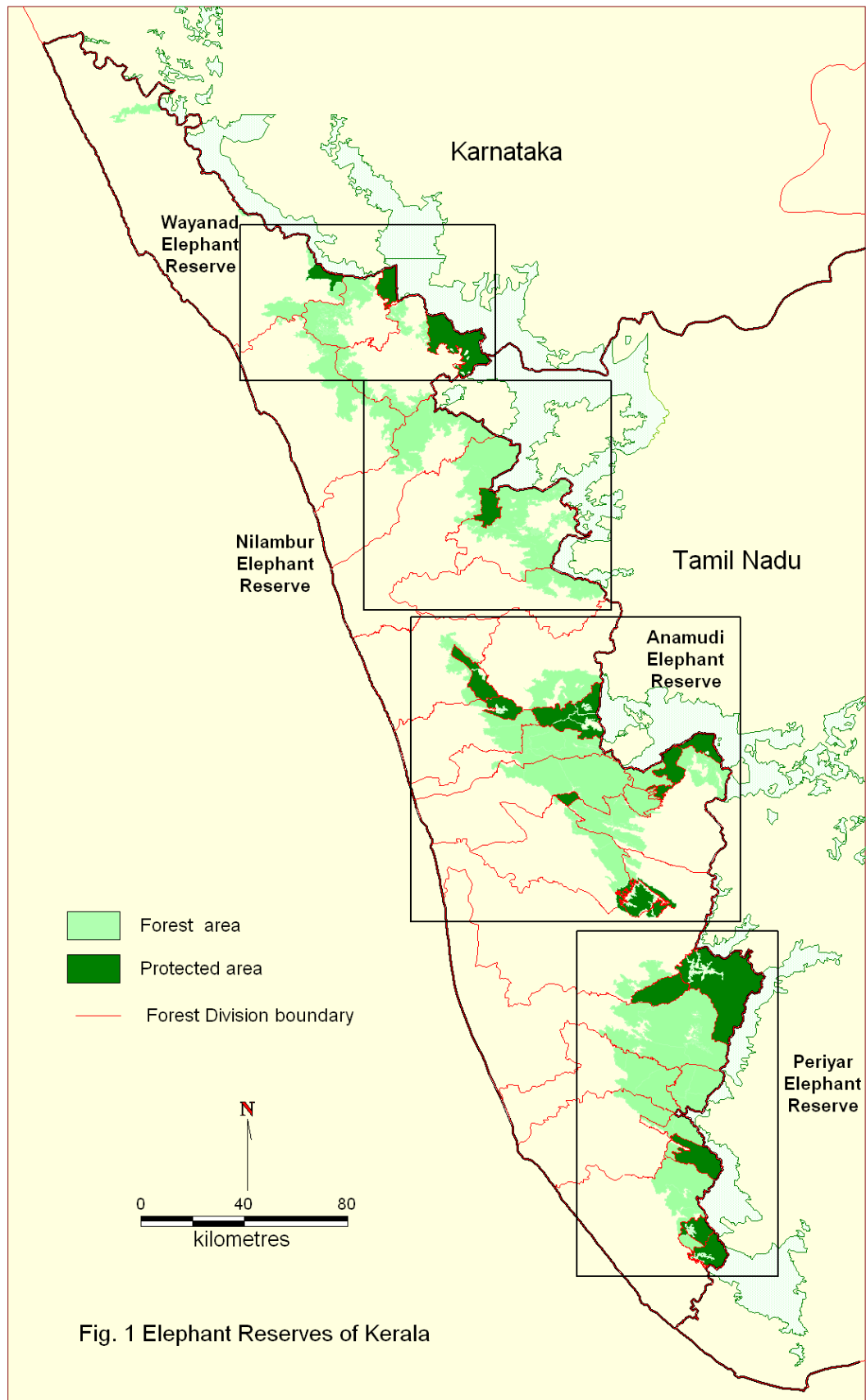


Fig. 1 Elephant Reserves of Kerala

Table 1. Elephant Reserves of Kerala State

Name of the Elephant Reserve	Protected Area & Territorial Forest Division (FD)	Remarks
Wayanad Elephant Reserve	<ol style="list-style-type: none"> 1. Wayanad WLS 2. Aralam WLS 3. North Wayanad FD 4. South Wayanad FD 5. Kannur FD 6. Kozhikode FD 	Meppadi Range in South Wayanad Forest Division and Thamarassery Range in Kozhikode Forest Division are excluded from this Elephant Reserve and transferred to Nilambur Elephant Reserve.
Nilambur Elephant Reserve	<ol style="list-style-type: none"> 1. Silent Valley NP 2. Nilambur North FD 3. Nilambur South FD 4. Kozhikode FD 5. Mannarkad FD 6. Palakkad FD 	Meppadi Range in Wayanad South Forest Division and Thamarassery Range in Kozhikode Forest Division are included in this Elephant Reserve. Ottappalam Range in Palakkad Forest Division is excluded from analysis.
Anamudi Elephant Reserve	<ol style="list-style-type: none"> 1. Parambikulam WLS 2. Peechi WLS 3. Chimmomy WLS 4. Thattekkad WLS 5. Chinnar WLS 6. Eravikulam NP 7. Idukki WLS 8. Nenmara FD 9. Chalakkudi FD 10. Thrissur FD 11. Vazhachal FD 12. Munnar FD 13. Malayattur FD 14. Kothamangalam FD 15. Mankulam FD 16. Marayoor Sandal Division 	<p>Thrissur Forest Division is excluded from analysis.</p> <p>Ayyappankovil Forest Range and Nagarampara Forest Range in Kottayam Forest Division are included in this Elephant Reserve.</p>
Periyar Elephant Reserve	<ol style="list-style-type: none"> 1. Periyar Tiger Reserve 2. Shendurney WLS 3. Thiruvananthapuram WLD (Peppara WLS & Neyyar WLS) 4. Kottayam FD 5. Ranni FD 6. Konni FD 7. Achankovil FD 8. Punalur FD 9. Thenmala FD 10. Thiruvananthapuram FD 11. ABP special FD 	<p>Ayyappankovil Range and Nagarampara Range in Kottayam Forest Division are excluded from this Elephant Reserve</p> <p>Kumily Range in Kottayam Forest Division and Anchal Range in Punalur Forest Division is excluded from analysis</p>

The toposheets of the forest areas were taken to the Divisional Forest Offices/Ranges and the blocks were demarcated by the Forest Range Officers and the field staff. The copies of such maps were sent to the Divisional Forest Offices with instructions on laying transects in the selected sample blocks. Transects were laid by the forest officers in the selected blocks and marked with paint/coloured biodegradable ribbons.

A proforma for the census was prepared and got printed along with instructions to the participants. The materials such as field compass, measuring tapes, note books and pencils were procured. The required number of kits containing these materials and the proforma were distributed to the offices of the Conservators. The Forest Range Officers later collected these items.

The actual census was carried out on two days. Block Count in selected blocks was carried out on 15-05-2010 and Dung Survey using Line Transect Sampling was carried out on 16-05-2010. The technical details of these techniques and statistical analysis employed are described in the next section.

2. METHODS

The two methods adopted for the population estimation were Block Count (Direct Sighting) and Dung Survey using Line Transect Sampling. Line Transect Sampling provided estimates of dung density. In order to convert elephant dung density into elephant density, dung decay rate is required. For this, the results of the dung decay experiments conducted in Wayanad Elephant Reserve were used. The details of the methodology are as follows.

2.1. Preparation of Block Maps

The total forest area of each Protected Area/Territorial Forest Division was divided into number of small blocks utilizing the Survey of India maps. The blocks that were demarcated in Wildlife Census-1997 were used for the present survey. A random sample of blocks was chosen in each Protected Area/Territorial Forest Division for enumeration. The total number of blocks sampled was 587. The details of the total number of blocks sampled and area sampled in each Elephant Reserve are given in Table 2.

Table 2. Total area of sampled blocks and number of blocks sampled

Elephant Reserve	Number of blocks sampled	Total area of sampled blocks (km ²)
Wayanad ER	86	578.842
Nilambur ER	95	839.589
Anamudi ER	193	1240.662
Peiyar ER	213	1814.833
Total	587	4473.925

2.2. Block Count Method - Direct Sighting

In each of the sample blocks, search was made for the presence of elephants by perambulating from 06.00 hours to 18.00 hours. The search team for each of the blocks consisted of a trained volunteer, a forest staff and a tribal tracker. The elephants sighted while traversing the area were counted in each block. The details such as block size, the habitat type(s) of the block, the number of elephants sighted, the age-sex distribution of the elephants sighted and type of habitat in which the elephants sighted were also recorded.

2.3. Line Transect Sampling - Elephant Dung Survey

The technique of Line Transect Sampling was adopted in all the sampled blocks. In each block, transect of about 2 km length was laid by marking trees with paint or colored biodegradable ribbons. These transects were covered on foot recording the perpendicular distance to the geometric center of the elephant dung piles. The perpendicular distance was measured using a tape. The details of total number of transects sampled in each Elephant Reserve are given in Table 3.

Table 3. Details of Line Transects laid in different Elephant Reserves

Elephant Reserve	Total number of transects	Total length of transect (km)	Total number of dung piles recorded
Wayanad ER	86	167.6	1767
Nilambur ER	95	190.9	981
Anamudi ER	193	384.6	2639
Periyar ER	213	427.9	2285
Total	587	1171	7672

2.4. Elephant Dung Decay Experiments

Elephant dung decay rate is expressed as the inverse of mean time to decay. The decay rate is a multiplicative factor in the formula for estimating elephant density. It is therefore important to precisely estimate this parameter. In 2010, the dung decay experiments could not be conducted. Therefore, the results of the dung decay experiments conducted in 2005 were used (Sivaram *et al.* 2006).

2.5. Analysis

2.5.1. Extent of Actual Elephant Habitat

Extent of actual elephant habitat is a crucial multiplication factor in extrapolating elephant population. Therefore, efforts were made to arrive at the actual extent of elephant habitat by consulting government notifications, published reports, forest working plans, etc. Apart from the forest areas, which are definitely devoid of elephants such as Thrissur Forest Division, Kumily Forest Range, the blocks that are devoid of elephants in various Forest Divisions, water bodies and other enclosures were accounted for and the actual elephant habitat worked out. The details of the area devoid of elephant and the actual elephant habitat for various Elephant Reserves are presented in Table 4. More details in this regard are given in Appendix II.

Table 4. Details of area devoid of elephant and actual area used for extrapolating elephant population in different Elephant Reserves of Kerala

Elephant Reserve	Forest area (km ²)	Effective forest area (km ²)*	Area devoid of elephants (km ²)	Actual area used for extrapolating elephant population (km ²)
Wayanad ER	1200	1101.05	166.89	934.16
Nilambur ER	1419	1255.71	113.41	1142.30
Anamudi ER	3728	3365.92	548.47	2817.45
Periyar ER	3742	3411.73	385.32	3026.41
Total	10,089	9134.41	1214.09	7920.32

* Effective forest area was computed for different Elephant Reserves by allocating the total effective forest area of the state (9400 km²) in proportion to the total forest area of territorial forest divisions falling under the respective Elephant Reserve

2.5.2. Estimation of Elephant Population by Block Count Method

The formulae used for estimating population of elephants in each of the Elephant Reserves (stratum) and variance and standard error of the estimated population and 95 per cent confidence interval are given below (Lahiri-Choudhury, 1991; Anonymous, 2004). The sum of the estimates across Elephant Reserves provided State level estimate.

Elephant population in the i^{th} stratum (\hat{N}_i) = $A_i \hat{D}_i$ ($i = 1, 2, \dots, p$)

Variance of the estimated elephant population in the i^{th} stratum

$$\text{Var}(\hat{N}_i) = \frac{A_i^2}{n_i(n_i - 1)} \sum_{j=1}^{n_i} \frac{(y_{ij} - y_i)^2}{(x_{ij} - x_i)^2}$$

Standard Error of \hat{N}_i in the i^{th} stratum

$$\text{SE}(\hat{N}_i) = \sqrt{\widehat{\text{var}}(\hat{N}_i)}$$

95% Confidence Limit for $\hat{N}_i = \hat{N}_i \pm 1.96 \text{ SE}(\hat{N}_i)$

where \hat{D}_i = Estimated density of elephants (No. of elephants/km²) in the i^{th} stratum

A_i = Total area of the i^{th} stratum

n_i = Number of blocks sampled in the i^{th} stratum

y_{ij} = Number of elephants sighted in the j^{th} block of the i^{th} stratum

y_i = Total number of elephants in sample blocks of the i^{th} stratum

x_{ij} = Area of j^{th} sample block of the i^{th} stratum

x_i = Total area of the sample blocks in the i^{th} stratum

\hat{N}_i = Estimated elephant population in the i^{th} stratum

The characteristics of the elephants sighted through Sample Block Count Method were also analyzed with respect to Age-Sex Classification, Bull to Cow ratio, Sub-Adult Male to Sub-Adult Female ratio, Percentage of Tuskers in Adult and Sub-Adult Population, Adult Cow to Calf ratio and Tusker to Makhna ratio and reported in the format suggested in the guidelines.

2.5.3. Dung Survey - Line Transect Sampling

The perpendicular distances to dung piles formed the input data for the estimation of dung density. The key formula used for the dung density estimation is given below.

$$\hat{D} = \frac{n\hat{f}(0)}{2L}$$

$$\hat{f}(0) = \frac{1}{\int_0^w g(x)}$$

The variance of \hat{D} is approximately

$$\widehat{Var}(\hat{D}) = \hat{D}^2 \cdot \left\{ \frac{\widehat{var}(n)}{n^2} + \frac{\widehat{var}[\hat{f}(0)]}{[\hat{f}(0)]^2} \right\}$$

An approximate $100(1 - 2\alpha)$ % confidence interval is given by

$$\hat{D} \pm z_{\alpha} \cdot \sqrt{\widehat{var}(\hat{D})}$$

($z = z_{0.025} = 1.96$ for a 95 % confidence interval)

where

n = number of dung piles enumerated

w = perpendicular distance to dung piles

L = length of transect (km)

$g(x)$ = the probability density function of detecting a dung pile in the survey area

x = perpendicular distance (m)

Univariate half normal distribution with the series expansion of simple polynomial was used as detection function for estimating the dung density. A five per cent truncation of the largest perpendicular distance values was adopted to improve the precision of the density estimates. The density estimates were obtained using the software DISTANCE 6.0 Release 2 developed by Thomas *et al.* (2009).

2.5.4. Estimating Elephant Population from Dung Density Estimates

The dung density of elephants was converted into animal density using the following formula.

$$\text{Elephant density (No./sq km)} = \frac{D}{DR} \times DDR$$

where D= Dung Density; DR= Defecation Rate and DDR= Dung Decay rate

The defecation rate of 16.33 per day, as obtained from wild elephants in Mudumalai by Watve (1992), was used in the above formula. As far as dung decay rate is concerned, the rate 0.0102 per day, obtained from dung decay experiments conducted in Wayanad Elephant Reserve in 2005 was used. The elephant population in each Elephant Reserves was estimated by multiplying density estimates with their respective extent of elephant habitat.

3. RESULTS

3.1 Block Count Method

3.1.1. Estimated Population of Elephants in different Elephant Reserves

A total of 1911 elephants were sighted during sample block count method. The estimated density and population of elephants for different Elephant Reserves of Kerala are presented in Table 5 and also indicated in Figure 2. The highest elephant density (No./km²) was found in Wayanad Elephant Reserve (0.5798), followed by Anamudi Elephant Reserve (0.5304), Periyar Elephant Reserve (0.4226) and Nilambur Elephant Reserve (0.1799). In terms of total number, Anamudi Elephant Reserve ranked first with 1494 elephants followed by Periyar (1279 elephants), Wayanad (542 elephants) and Nilambur Elephant Reserve (205 elephants). The extrapolated wild elephant population at the State level by Block Count Method was 3520 elephants with 95 per cent confidence interval of 3054 to 3987.

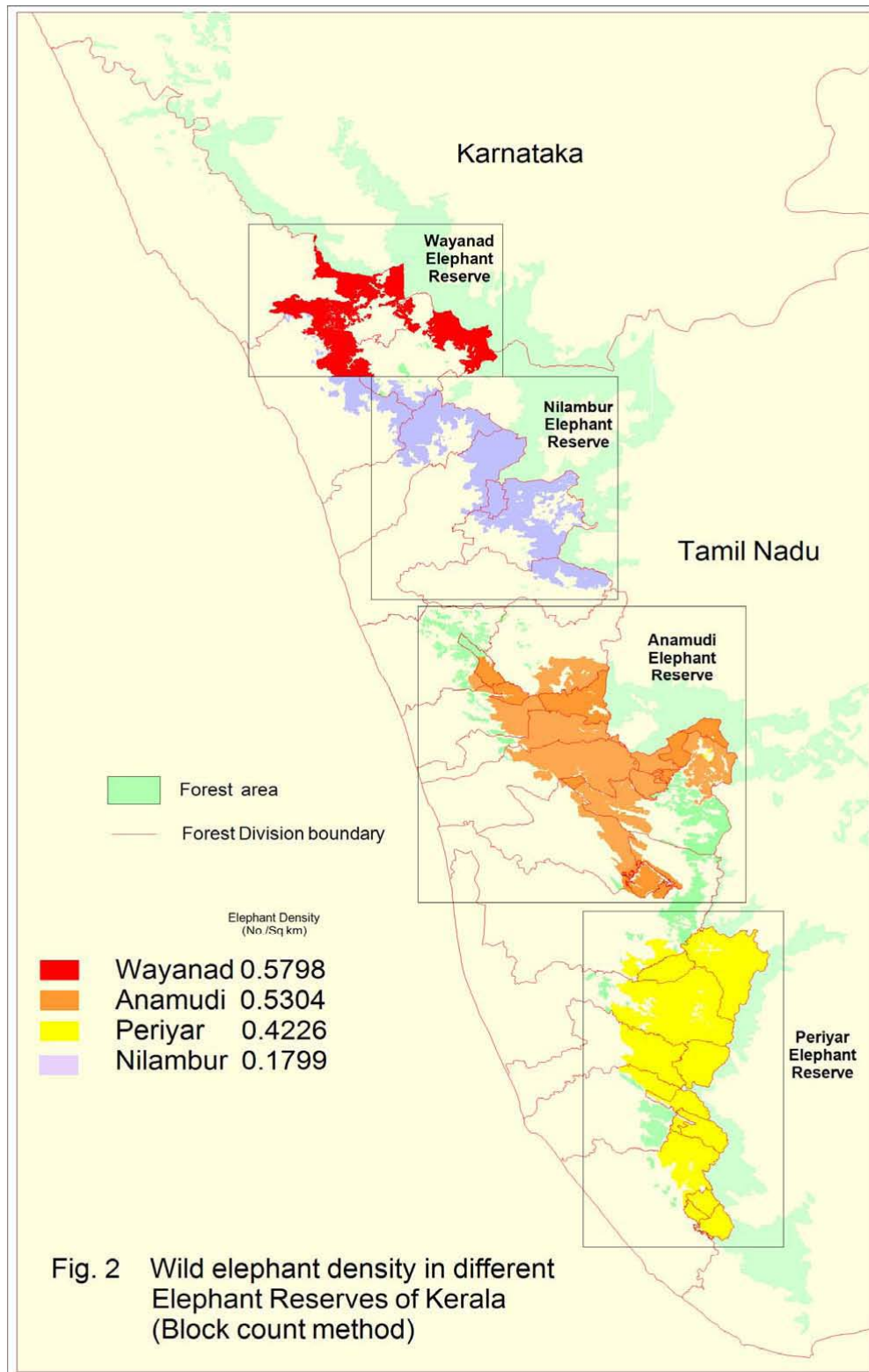
3.1.2 Estimated Population of Elephants in different Territorial Forest Divisions and Protected Areas

The details of the elephant density and estimated elephant numbers in different Protected areas and Territorial Forest Divisions are presented in Table 6 and also indicated in Figure 3. The highest density of elephants was found in the Wayanad Wildlife Sanctuary (2.1) followed by the Idukki Wildlife Division (1.3). The lowest density was found in the Thenmala Forest Division, Marayoor Sandal Division and ABP Special Division followed by Silent Valley NP (0.01).

Table 5. Estimated population of elephants in the Elephant Reserves of Kerala

Elephant Reserve	Extent of effective elephant habitat (km²)	Number of elephants sighted in sampled blocks	Estimated elephant density (No./km²)	Extrapolated number of elephants	SE*	LCL	UCL
Wayanad ER	934.16	335	0.5798	542	21.09	500	583
Nilambur ER	1142.30	151	0.1799	205	21.09	164	247
Anamudi ER	2817.45	658	0.5304	1494	107.85	1283	1706
Periyar ER	3026.41	767	0.4226	1279	87.85	1107	1451
Total	7920.32	1911		3520		3054	3987

*SE- Standard Error; LCL – 95% Lower Confidence Limit; UCL- 95% Upper Confidence Limit



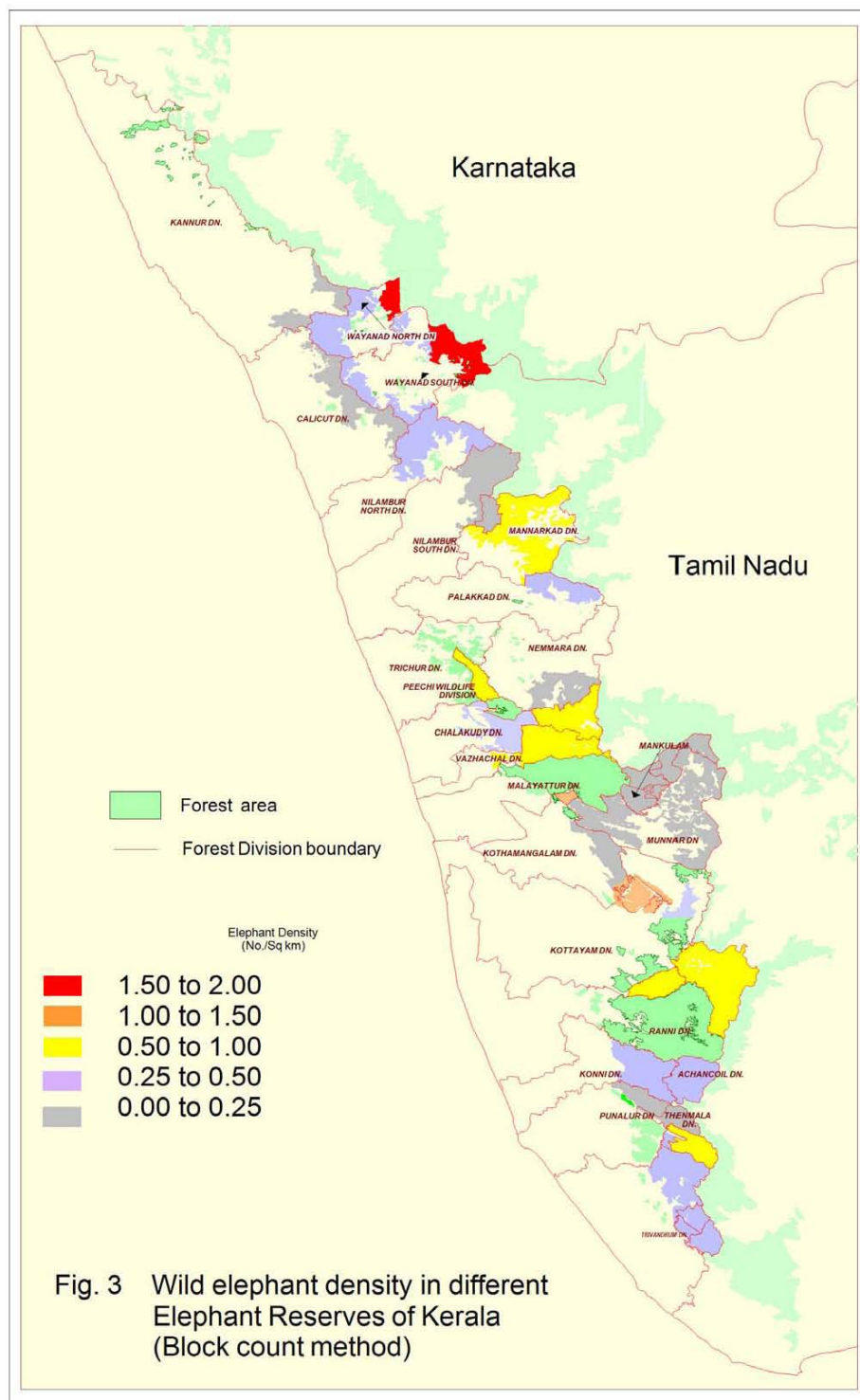


Table 6. Estimated population of elephants in different Forest Divisions of Kerala

Protected area/Territorial Forest division	Number of elephants sighted in the sampled blocks	Estimated elephant density (No./km²)
Wayanad WLS	224	2.0718
Aralam WLS	7	0.2461
Wayanad North	33	0.3116
Wayanad South	42	0.2521
Kannur	14	0.1220
Kozhikode	26	0.2494
Silent Valley NP	1	0.0100
Nilambur North	73	0.2536
Nilambur South	33	0.1924
Mannarkad	16	0.9385
Palakkad	17	0.2764
Parambikulam WLS	74	0.5440
Peechi WLD	38	0.5184
Munnar WLD	29	0.1951
Idukki WLD	83	1.2976
Nenmara	4	0.0550
Chalakkudi	30	0.2699
Vazhachal	100	0.7171
Munnar	9	0.0745
Malayattur	284	1.2525
Kothamangalam	4	0.0966
Mankulam	1	0.0794
Marayoor Sandal Division	0	0.0000
Periyar Tiger Reserve	211	0.5430
Shendurney WLS	107	0.8931
Thiruvananthapuram WLD	39	0.2981
Kottayam	7	0.0749
Ranni	186	0.4378
Konni	43	0.2577
Achankovil	51	0.3178
Punalur	37	0.4395
Thenmala	0	0.0000
Thiruvananthapuram	88	0.4442
ABP Special Division	0	0.0000

3.1.3. Population Characteristics of Elephants in different Elephant Reserves

The age-sex distribution of the elephants sighted through Sample Block Count in different Elephant Reserves is presented in Table 7. The age-sex distribution for various Protected Areas and Territorial Forest Divisions is given in Table 8. The sex ratio of elephants in various age categories, percentage of tuskers in adult and sub-adult population and ratio of tuskers to makhna for various Elephant Reserves and for the State are presented in Table 9.

Table 7. Age-sex Distribution of elephants in different Elephant Reserves in Kerala

Elephant Reserves	Adult Bulls (>240 cm)*			Adult Cows (>210 cm)	Adult/ Sub-Adult US				Sub-Adult Bulls (151-240 cm)			Sub-Adult cows (151-210 cm)	Juvenile (121-150 cm)	Calf (<120 cm)	Grand Total
	T	Mk	Total		(>240 cm)	(211-240 cm)	152-210 cm)	Total	T	Mk	Total				
Wayanad ER	57	5	62	139	-	-	-	13	13	-	13	23	36	49	335
Nilambur ER	25	5	30	45	-	-	-	11	10	-	10	17	17	21	151
Anamudi ER	45	9	54	269	-	-	-	63	47	-	47	98	54	73	658
Periyar ER	122	15	137	315	-	-	-	25	43	-	43	83	72	92	767
Total	249	34	283	768	-	-	-	112	113	-	113	221	179	235	1911

* Height of the elephants T – Tusker; Mk – Makhna (Tuskless Bull); US – Unknown Sex

Table 8. Age – Sex distribution of elephants in different Forest divisions of Kerala

Protected Area / Forest Territorial Division	Adult Bulls (>240 cm*)			Adult Cows (>210 cm)	Adult/Sub- adult US	Sub-Adult Bulls (151-240 cm)			Sub-Adult Cows (151 - 210 cm)	Juvenile (121-150 cm)	Calf (< 120 cm)	Grand Total
	T	Mk	Total			T	Mk	Total				
Wayanad WLS	30	3	33	105	1	10	-	10	17	23	35	224
Aralam WLS	-	-	-	2	3	-	-	-	-	-	2	7
Wayanad North	9	1	10	13	1	1	-	1	2	2	4	33
Wayanad South	12	1	13	13	-	1	-	1	1	10	4	42
Kannur	4	-	4	4	-	1	-	1	1	2	2	14
Kozhikode	3	1	4	6	11	-	-	-	2	1	2	26
Silent Valley NP	-	-	-	-	-	1	-	1	-	-	-	1
Nilambur North	11	1	12	23	4	6	-	6	8	10	10	73
Nilambur South	5	3	8	10	2	1	-	1	4	3	5	33
Mannarkad	3	-	3	4	1	-	-	-	3	2	3	16
Palakkad	5	-	5	4	1	2	-	2	2	-	3	17
Parambikulam WLS	5	1	6	31	7	6	-	6	9	7	8	74
Peechi WLD	1	-	1	18	2	3	-	3	5	6	3	38
Munnar WLD	2	-	2	18	-	3	-	3	2	2	2	29
Idukki WLD	2	4	6	43	12	1	-	1	17	2	2	83
Nenmara	1	-	1	2	-	-	-	-	-	-	1	4
Chalakkudi	3	2	5	16	1	-	-	-	5	1	2	30
Vazhachal	4	-	4	45	3	9	-	9	16	7	16	100

Table 8 contd...

Protected Area / Forest Territorial Division	Adult Bulls (>240 cm*)			Adult Cows (>210 cm)	Adult/Sub- Adult US	Sub-Adult Bulls (151-240 cm)			Sub-Adult Cows (151 - 210 cm)	Juvenile (121-150 cm)	Calf (< 120 cm)	Grand Total
	T	Mk	Total			T	Mk	Total				
Munnar	1	-	1	1	2	2	-	2	3	-	-	9
Malayattur	25	2	27	92	36	23	-	23	39	28	39	284
Kothamangalam	-	-	-	1	-	-	-	-	2	-	-	4
Mankulam	1	-	1	-	-	-	-	-	-	-	-	1
Marayoor Sandal Division	-	-	-	-	-	-	-	-	-	-	-	-
Periyar Tiger Reserve	18	3	22	89	5	10	-	10	30	20	36	211
Shendurney WLS	27	-	27	34	4	10	-	10	10	14	8	107
Thiruvananthapuram WLD	8	-	8	17	-	1	-	1	4	6	3	39
Kottayam	-	-	-	5	-	-	-	-	2	-	-	7
Ranni	26	-	26	86	9	6	-	6	20	9	30	186
Konni	6	2	8	17	-	3	-	3	3	7	5	43
Achankovil	16	3	19	16	1	1	-	1	1	7	6	51
Punalur	6	3	9	14	1	5	-	5	3	4	1	37
Thenmala	-	-	-	-	-	-	-	-	-	-	-	-
Thiruvananthapuram	15	4	19	39	5	7	-	7	10	5	3	88
ABP Special Division	-	-	-	-	-	-	-	-	-	-	-	-
Total	249	34	283	768	112	113	-	113	221	179	235	1911

* Height of the elephants T – Tusker; Mk – Makhna (Tusk less Bull); US – Unknown Sex

Table 9. Population characteristics of wild elephants in different Elephant Reserves of Kerala

Population Characteristics	Elephant Reserve				Total
	Wayanad	Nilambur	Anamudi	Periyar	
Adult Male: Adult Female (Bull: Cow)	1: 2.24	1: 1.5	1: 4.98	1: 2.30	1: 2.71
Sub-Adult Male: Sub-Adult Female	1: 1.77	1: 1.7	1: 2.09	1: 1.93	1: 1.96
% Tusker in Adult and Sub-adult population	28%	31%	17.3%	27.4%	24.2%
Adult Cow: Calf	2.84: 1	2.14: 1	3.68: 1	3.42: 1	3.27: 1
Tusker: Makhna in Adults	11.4: 1	5: 1	5: 1	8.13: 1	7.32: 1

3.2. Elephant Dung Survey

3.2.1. Dung Density Estimates based on Line Transect Survey

Table 10 shows the dung density estimates for different Elephant Reserves. Table 11 shows dung density estimates for different Territorial Forest Divisions/ Protected Areas.

Table 10. Estimated elephant dung density in different Elephant Reserves of Kerala

Elephant Reserve	Dung density (No. of dung piles /km ²)	LCL	UCL	CV%
Wayanad	2541.5	1969.9	3279.0	0.1289
Nilambur	906.63	749.27	1097.1	0.0966
Anamudi	1185.4	1012.3	1388.2	0.0804
Periyar	957.47	804.54	1139.5	0.0886

SE- Standard Error; LCL- 95% Lower Confidence Limit; UCL- 95% Upper Confidence Limit.

Table 11. Estimated elephant dung density in different Forest Divisions in Kerala

Protected area/ Territorial Forest Division	Dung density (No. of dung piles/km²)	LCL	UCL	CV%
Wayanad WLS	4744.6	3631.9	6198.2	12.93
Aralam WLS	2524.9	371.3	17168.0	79.26
Wayanad North	1270.5	804.6	2006.1	22.31
Wayanad South	1677.0	1093.8	2571.3	20.63
Kannur	669.8	338.6	1324.9	33.35
Kozhikode	1610.6	1026.0	2528.3	21.92
Silent Valley NP	1086.3	631.17	1869.5	25.45
Nilambur North	824.8	586.7	1159.4	17.02
Nilambur South	1204.6	797.2	1820.4	19.99
Mannarkad	982.8	580.7	1663.6	24.95
Palakkad	188.6	122.3	290.7	21.47
Parambikulam WLS	2115.3	1540.0	2905.4	15.50
Peechi WLD	1319.2	509.9	3413.1	44.50
Munnar WLD	1158.7	760.9	1764.6	20.66
Idukki WLD	1755.7	1146.1	2689.5	19.78
Nenmara	921.4	464.4	1828.4	31.62
Chalakkudi	425.5	235.3	769.7	28.75
Vazhachal	2488.5	1925.8	3113.1	11.70
Munnar	330.4	227.9	479.0	18.52
Malayattur	1241.4	902.7	1707.2	15.81
Kothamangalam	101.7	21.6	477.7	72.22
Mankulam	2314.4	1052.6	5088.9	25.54
Marayoor Sandal Division	168.0	74.8	377.4	39.57
Periyar	1902.8	1288.3	2810.3	19.38
Shendurney WLS	2872.2	2194.0	3760.0	12.62
Thiruvananthapuram WLD	283.5	183.2	438.6	21.44
Kottayam	589.8	275.0	1265.2	36.87
Ranni	331.9	263.7	417.8	11.59
Konni	847.5	538.7	1333.0	22.43
Achankovil	612.7	448.5	837.0	15.60
Punalur	307.9	85.5	1108.2	59.75
Thenmala	98.6	43.6	223.0	40.04
Thiruvananthapuram	685.6	432.0	1088.2	22.93
ABP Special Division	351.3	187.1	659.5	28.50

SE- Standard Error; LCL- 95% Lower Confidence Limit; UCL- 95% Upper Confidence Limit

3.3. Estimated Elephant Population based on Dung Density

An attempt was made to estimate the elephant density and elephant population for different Elephant Reserves based on estimates of dung density, dung decay rate and defecation rate. The pooled dung density estimates irrespective of vegetation types presented in Table 10, were used for estimating elephant density.

The estimated density and population of elephants are presented in Table 12 for different Elephant Reserves. The estimated wild elephant population based on dung density for the State was 6068 with the 95 per cent confidence interval ranging from 4986 to 7293. The highest density (No./km²) was found in Wayanad Elephant Reserve (1.5875), followed by Anamudi Elephant Reserve (0.7404), Periyar Elephant Reserve (0.5981) and Nilambur Elephant Reserve (0.5663) and in terms of extrapolated number of elephants Anamudi Elephant Reserve ranked first with 2086 elephants followed by Periyar Elephant Reserve (1810 elephants), Wayanad (1483 elephants) and Nilambur (647 elephants).

Table 13 presents the estimated elephant density and population for various Forest Divisions and Protected Areas.

Table 12. Estimated density and population of elephants in different Elephant Reserves based on dung density estimates

Elephant Reserve	Extent of effective elephant habitat	Elephant Density (No. of elephants /km ²)	No. of elephants	LCL	UCL
Wayanad ER	934.16	1.5875	1483	1149	1913
Nilambur ER	1142.30	0.5663	647	535	783
Anamudi ER	2817.45	0.7404	2086	1781	2443
Periyar ER	3026.41	0.5981	1810	1521	2154
Total	7920.32		6026	4986	7293

Note: Elephant density was estimated with the decay rate of 0.0102 and the defecation rate of 16.33
LCL – 95% Lower Confidence Limit; UCL- 95% Upper Confidence Limit

Table 13. Estimated density and population of elephants in different Forest Divisions based on dung density estimates

Protected area/Territorial Forest Division	Elephant density (No. of elephants/ km²)	LCL	UCL
Wayanad WLS	2.964	2.269	3.872
Aralam WLS	1.577	0.232	10.723
Wayanad North	0.794	0.503	1.253
Wayanad South	1.047	0.683	1.606
Kannur	0.418	0.211	0.828
Kozhikode	1.006	0.641	1.579
Silent Valley NP	0.679	0.394	1.168
Nilambur North	0.515	0.366	0.724
Nilambur South	0.752	0.498	1.137
Mannarkad	0.614	0.363	1.039
Palakkad	0.118	0.076	0.182
Parambikulam WLS	1.321	0.962	1.815
Peechi WLD	0.824	0.318	2.132
Munnar WLD	0.724	0.475	1.102
Idukki WLD	1.097	0.716	1.680
Nenmara	0.576	0.290	1.142
Chalakkudi	0.266	0.147	0.481
Vazhachal	1.554	1.203	1.944
Munnar	0.206	0.142	0.299
Malayattur	0.775	0.564	1.066
Kothamangalam	0.064	0.013	0.298
Mankulam	1.446	0.657	3.179
Marayoor Sandal Division	0.105	0.047	0.236
Periyar Tiger Reserve	1.189	0.805	1.755
Shendurney WLS	1.794	1.370	2.349
Thiruvananthapuram WLD	0.177	0.114	0.274
Kottayam	0.368	0.172	0.790
Ranni	0.207	0.165	0.261
Konni	0.529	0.336	0.833
Achankovil	0.383	0.280	0.523
Punalur	0.192	0.053	0.692
Thenmala	0.062	0.027	0.140
Thiruvananthapuram	0.428	0.270	0.680
ABP Special Division	0.219	0.117	0.412

4. DISCUSSION

In Kerala, during the years 1993, 1997 and 2002, estimation of wild elephant population was undertaken along with all the major mammals. In 2005, 2007, and 2010 the population estimation was undertaken exclusively for elephants. Both direct and indirect methods were used. The scope, methods adopted and coverage of the census varied significantly from census to census (Table 14). Also the decay rate used for converting dung density into elephant density and the effective elephant habitat used differed significantly across the census years. This makes the comparison of census figures a tricky task. Further, the Elephant Reserve concept has also been introduced since 2005 and the census was organized in all the four Elephant Reserves of Kerala with the aim to estimate the elephant population in each of the Reserves. Under these circumstances, an attempt was made to compare the trends in the abundance of elephant population in different Elephant Reserves of Kerala. Table 15 provides the estimated figures of population during different years.

Table 14. Different methods employed for wild animal census in the forests of Kerala State

Census year	Dates of census and methods followed	Coverage	Scope
1993	Line transect-direct sighting on 30-04-1993 Line transect–dung count on 01-05-1993 Total count on 02-05-1993 Pug mark count on 03-05-1993	All the blocks	All the major mammals
1997	Line transect direct on 29-04-1997 Block count on 30-04-1997 Line transect – dung count on 01-05-1997 Pug mark count on 02-05-1997	Sample of blocks (30 % of total blocks)	All the major mammals
2002	Block count on 07-05-2002 Line transect –dung count on 08-05-2002 Line transect- direct sighting on 09-05-2002 Pug mark count on 10-05-2002	All the blocks	All the major mammals
2005	Block count on 05-05-2005 Line transect- dung count on 06-05-2005	Sample of blocks (34% of total blocks)	Elephant Only
2007	Block count on 07-05-2007 Line transect- dung count on 09-05-2007	Sample of blocks (50% of total blocks)	Elephant Only
2010	Block count on 15-05-2010 Line transect-dung count on 16-05-2010	Sample of blocks (50% of total blocks)	Elephant Only

Table 15. Population estimation of wild elephants during different census in Kerala

Year	No. of elephants sighted	Estimated elephant population	Methods	References
1989	-	3500	Total count	Karunakaran (1990). Proceedings of the Elephant Symposium; February 1990
1993	2388	4286	100% blocks covered; Line transect dung survey	Anonymous (1993). Wildlife Census – Kerala 1993
1997	1163	5737 LCL 4290 UCL 7184	30 % blocks covered; Population was estimated based on average estimate of elephant density from line transect sampling (direct sighting) and dung survey	Easa and Jayaraman (2002). Population Estimation of Major Mammals in the Forests of Kerala – 1997
2002	2296	6939 LCL 5649 UCL 8546	100 % blocks covered; Population was estimated based on dung survey	Easa, Sivaram and Jayson (2002). Population Estimation of Major Mammals in the Forests of Kerala – 2002
2005	1623	3564 LCL 2971 UCL 4157 (by Block Count Method)	34 % blocks covered	Sivaram, Ramachandran, Nair and Jayson (2006). Population Estimation of Wild Elephants in the Elephant Reserves of Kerala – 2005
		5135 LCL 4069 UCL 6508 (by Dung Survey)		
2007	1679	3002 LCL 2543 UCL 3467 (by Block Count Method)	50 % blocks covered	Sivaram, Ramachandran, Nair and Jayson (2007). Population Estimation of Wild Elephants in the Elephant Reserves of Kerala – 2007
		6068 LCL 4950 UCL 7461 (by Dung Survey)		
2010	1911	3520 LCL 3054 UCL 3987 (by Block Count Method)	50 % blocks covered	Wild Elephant Population Estimation - 2010(Present)
		6026 LCL 4986 UCL 7293 (by Dung Survey)		

4.1. Trends in the number of Elephants sighted and Elephant density

The estimated elephant population of the State using Block Count Method for the census year 2010 was 3520. This is higher than the estimated population of 3002 elephants in the year 2007. This could be attributed to the higher number of sightings in 2010 than that in 2007. The increasing trend was seen in all the Elephant Reserves.

The wild elephants sighted through the Block Count Method in various Forest Divisions/Protected areas during the census years 2005, 2007 and 2010 were assigned properly to four Elephant Reserves of Kerala and given in Table 16, Table 17, Table 18 and Table 19 respectively. The trend analysis for the period 2007 to 2010 revealed that there was an increasing trend in the elephant density in 19 Forest Divisions/Protected areas. A decreasing trend was observed in 13 Divisions viz., Wayanad South, Silent Valley NP, Parambikulam WLS, Munnar WLD, Nenmara, Chalakkudi, Munnar, Kothamangalam, Mankulam, Periyar Tiger Reserve, Thiruvananthapuram WLD, Kottayam and ABP Special Division. There was no sighting of elephants in Thenmala Division both in 2007 and 2010. Marayoor Sandal Division which was created recently recorded no elephants. ABP Special Division, which recorded 8 elephants in 2007, has not recorded any elephant this time. The high variation (decrease/increase) in elephant density in some of the forest divisions could be due to the role of local factors.

Table 16. Comparison of elephant density in different Forest Divisions/Protected Areas included in Wayanad Elephant Reserve (by Sample Block Count Method)

Forest Division/ Protected Area	In 34 % of blocks on 05-05-2005		In 50% of Blocks on 07-05-2007		In 50% of Blocks on 15-05-2010	
	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)
Wayanad WLS	288	2.3978	221	1.7547	224	2.0718
Aralam WLS	5	0.3019	1	0.0330	7	0.2461
Wayanad North	16	0.1647	14	0.1182	33	0.3116
Wayanad South	24	0.1385	60	0.3217	42	0.2521
Kannur	9	0.1680	7	0.0806	14	0.1220
Kozhikode	14	0.1267	6	0.0587	26	0.2494
Total	356		309		346	

Table 17. Comparison of elephant density in different Forest Divisions/Protected Areas included in Nilambur Elephant Reserve (by Sample Block Count Method)

Forest Division/ Protected Area	In 34 % of blocks on 06-05-2005		In 50% of Blocks on 07-05-2007		In 50% of Blocks on 15-05-2010	
	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)
Silent Valley NP	5	0.1244	14	0.2877	1	0.0100
Nilambur North	23	0.1436	6	0.0277	73	0.2536
Nilambur South	47	0.5306	24	0.1129	33	0.1924
Mannarkad	46	0.2941	18	0.0699	16	0.9385
Palakkad	13	0.2109	3	0.0360	17	0.2764
Total	134		65		140	

Table 18. Comparison of elephant density in different Forest Divisions/Protected Areas included in Anamudi Elephant Reserve (by Sample Block Count Method)

Forest Division/ Protected Area	In 34 % of blocks on 06-05-2005		In 50% of Blocks on 07-05-2007		In 50% of Blocks on 15-05-2010	
	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)
Parambikulam WLS	88	0.8026	113	0.8651	74	0.5440
Peechi WLD	34	0.9392	14	0.1910	38	0.5184
Munnar Wildlife	76	1.7159	65	1.0693	29	0.1951
Idukki WLD	36	0.3275	35	0.2062	83	1.2976
Nenmara	12	0.2419	11	0.1511	4	0.0550
Chalakkudi	108	0.6317	60	0.3489	30	0.2699
Vazhachal	17	0.1652	34	0.3045	100	0.7171
Munnar	162	0.6758	174	0.7525	9	0.0745
Malayattur	4	0.2761	14	0.6151	284	1.2525
Kothamangalam	7	0.0796	13	0.1370	4	0.0966
Mankulam	80	0.5364	47	0.4160	1	0.0794
Marayoor Sandal Division	-	-	-	-	0	0.0000
Total	624		580		656	

Table 19. Comparison of elephant density in different Forest Divisions/Protected Areas included in Periyar Elephant Reserve (by Sample Block Count Method)

Forest Division/ Protected Area	In 34 % of blocks on 06-05-2005		In 50% of Blocks on 07-05-2007		In 50% of Blocks on 15-05-2010	
	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)	No. of elephants sighted	Density (No./km ²)
Periyar	241	0.8933	236	0.6160	211	0.5430
Shendurney WLS	61	0.5054	102	0.8889	107	0.8931
Thiruvananthapuram WLD	13	0.1578	33	0.3334	39	0.2981
Kottayam	15	0.1744	40	0.3214	7	0.0749
Ranni	63	0.2176	166	0.3897	186	0.4378
Konni	27	0.2427	28	0.1582	43	0.2577
Achankovil	25	0.2303	31	0.1989	51	0.3178
Punalur	7	0.0686	20	0.1780	37	0.4395
Thenmala	0	0.0000	0	0.0000	0	0.0000
Thiruvananthapuram	42	0.3008	61	0.2520	88	0.4442
ABP Special Division	15	0.4122	8	0.2198	0	0.0000
Total	509		725		769	

4.2 .Trends in Elephant Dung Density

Block Count and Dung Count Methods are two different methods which need not provide similar estimates due to associated drawbacks. The Block Count Method often involves undercounting and thus underestimation of elephant population. The Dung Count Method is often found to provide overestimates.

An attempt has been made here to compare the census results of 2007 and 2010. The estimated elephant population of the State using dung survey for the census year 2010 was 6026 whereas it was 6068 in 2007. The decrease of 42 elephants in 2010 is insignificant. An increase in elephant population was seen in Wayanad and Periyar Elephant Reserves. On the other hand, decrease in number was recorded in Nilambur and Anamudi Elephant Reserves.

Analysis of trends over the period 2007 to 2010 in dung density in different divisions is presented in Tables 20 to 23 which indicated an increasing trend in the dung density estimates except in fourteen Forest Divisions viz., Wayand WLS, Silent Valley NP, Nilambur South, Palakkad, Parambikulam WLS, Idukki WLD, Vazhachal, Munnar, Malayattur, Kothamangalam, Periyar, Ranni, Thenmala and ABP Special Division. The newly created Marayoor Sandal Division recorded 168 dung piles per km². The high variation (decrease/increase) dung density in some of the forest divisions could be due to the role of local factors.

Table 20. Comparison of dung density of wild elephants in different Forest Divisions/ Protected Areas included in Wayanad Elephant Reserve (by Line transect- Dung survey)

Forest Division/ Protected Area	In 34% of blocks on 06-05-2005		In 50% of blocks on 09-05-2007		In 50% of blocks on 16-05-2010	
	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%
Wayanad WLS	659.5	32.6	6162.5	13.9	4744.6	12.9
Aralam WLS	510.6	35.5	1088.1	56.6	2524.9	79.3
Wayanad North	462.5	27.5	743.8	27.8	1270.5	22.3
Wayanad South	4766.2	18.7	1354.2	23.6	1677.0	20.6
Kannur	337.6	60.9	110.4	50.5	669.8	33.4
Kozhikode	230.8	22.5	916.7	22.0	1610.6	21.9

Table 21. Comparison of dung density of wild elephants in different Forest Divisions/ Protected Areas included in Nilambur Elephant Reserve (by Line transect – Dung survey)

Forest Division/ Protected Area	In 34% of blocks on 06-05-2005		In 50% of blocks on 09-05-2007		In 50% of blocks on 16-05-2010	
	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%
Silent Valley NP	2266.3	14.7	1570.9	22.7	1086.3	25.5
Nilambur North	727.9	19.0	375.4	21.9	824.8	17.0
Nilambur South	409.1	23.5	1075.5	15.4	1204.6	20.0
Mannarkad	176.3	23.3	435.7	24.8	982.8	25.0
Palakkad	0.0	0.0	1441.4	38.9	188.6	21.5

Table 22. Comparison of dung density of wild elephants in different Forest Divisions/ Protected Areas included in Anamudi Elephant Reserve (by Line transect – Dung survey)

Forest Division/ Protected Area	In 34% of blocks on 06-05-2005		In 50% of blocks on 09-05-2007		In 50% of blocks on 16-05-2010	
	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%
Parambikulam WLS	3079.7	13.9	2404.0	18.1	2115.3	15.5
Peechi WLD	370.8	47.4	790.8	26.9	1319.2	44.5
Munnar WLD	1817.8	23.9	825.2	19.8	1158.7	20.7
Idukki WLD	2814.4	33.5	2262.3	16.9	1755.7	19.8
Nenmara	138.1	31.8	543.9	26.9	921.4	31.6
Chalakkudi	1053.3	37.1	751.1	21.6	425.5	28.8
Vazhachal	2919.0	18.1	2509.2	16.0	2488.5	11.7
Munnar	628.4	22.4	962.3	24.2	330.4	18.5
Malayattur	1633.0	17.1	1669.8	15.5	1241.4	15.8
Kothamangalam	62.7	86.6	633.6	37.3	101.7	72.2
Mankulam	541.2	66.0	673.6	38.8	2314.4	25.5
Marayoor Sandal Division	-	-	-	-	168.0	39.6

Table 23. Comparison of dung density of wild elephants in different Forest Divisions/ Protected Areas included in Periyar Elephant Reserve (by Line transect – Dung survey)

Forest Division/ Protected Area	In 34% of blocks on 06-05-2005		In 50% of blocks on 09-05-2007		In 50% of blocks on 16-05-2010	
	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%	Density (No. of dung piles/ km ²)	CV%
Periyar Tiger Reserve	2233.3	16.6	2055.6	11.9	1902.8	19.4
Shendurney WLS	1702.9	29.7	2212.6	16.8	2872.2	12.6
ThiruvananthapuramWLD	583.0	32.8	222.4	22.0	283.5	21.4
Kottayam	428.7	60.8	580.4	24.1	589.8	36.9
Ranni	486.3	29.5	898.2	13.2	331.9	11.6
Konni	878.3	31.9	709.5	22.6	847.5	22.4
Achankovil	240.0	13.3	423.7	13.9	612.7	15.6
Punalur	420.0	41.2	240.6	64.4	307.9	59.8
Thenmala	392.6	25.9	110.0	46.6	98.6	40.0
Thiruvananthapuram	395.2	28.7	561.5	25.8	685.6	22.9
ABP Special Division	462.9	37.3	620.2	30.2	351.3	28.5

4.3. Population Characteristics of Elephants

Only direct observation of elephants will yield population characteristics such as age structure, sex ratio, etc. The trends in the age-sex distribution in various Elephant Reserves are presented in Table 24.

Table 24. Comparison of population characteristics of wild elephants in Kerala State during three consecutive exclusive Elephant Census 2005, 2007 and 2010

Population characteristics	Year	Elephant Reserves				Total
		Wayanad	Nilambur	Anamudi	Periyar	
Adult Male: Adult Female (Bull: Cow)	2005	1: 2.60	1: 1.23	1: 4.69	1: 3.93	1: 3.38
	2007	1: 1.95	1: 1.44	1: 4.52	1:2.87	1: 2.96
	2010	1: 2.24	1: 1.5	1: 4.98	1: 2.30	1: 2.71
Sub-Adult Male: Sub-Adult Female	2005	1: 0.91	1: 1.33	1: 2.85	1: 2.14	1: 1.77
	2007	1: 1.18	1: 4	1: 3.25	1: 1.84	1: 1.99
	2010	1: 1.77	1: 1.7	1: 2.09	1: 1.93	1: 1.96
Adult Cow: Calf	2005	3.89: 1	2.92: 1	5.02: 1	4.07: 1	4.27: 1
	2007	3.69: 1	2.56: 1	3.75: 1	4.01: 1	3.78: 1
	2010	2.84: 1	2.14: 1	3.68: 1	3.42: 1	3.27: 1
% Tusker in Adult and Sub- Adult population	2005	29.33%	37.27%	15.16%	16.95%	20.64%
	2007	33.33%	27.78%	12.98%	23.67%	21.86%
	2010	28%	31%	17.3%	27.4%	24.2%
Tusker: Makhna in Adults	2005	6.13: 1	5.2: 1	5.1: 1	4.8: 1	5.27: 1
	2007	10: 1	4.33: 1	2.94: 1	10.33: 1	6.26: 1
	2010	11.4: 1	5: 1	5: 1	8.13: 1	7.32: 1

5. RECOMMENDATIONS/SUGGESTIONS

1. Stratification is an important means by which precision of the estimates can be improved. In the survey conducted so far, prior stratification could not be effected for lack of information. The GIS technology enables to have the survey design drawn in the maps along with relevant details such as habitat type. In future censuses, such maps should be made available well ahead of the survey.
2. The decay rate is an important factor in converting dung density into elephant density. Therefore, steps should be taken to determine the decay rates scientifically in different seasons in all the Elephant Reserves. This job can be assigned to research organizations.
3. The actual extent of elephant habitat is crucial in extrapolating elephant population. Therefore, concerted efforts should be made to estimate the extent of elephant habitat in each of the Elephant Reserves.
4. The population characteristics of wild elephants in the State should be monitored at regular intervals.
5. Proper training on field methods including identification of different age-sex classes of elephants is important especially while involving large number of people.

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7. APPENDICES

Appendix I

Methods commonly used for estimating wildlife population

The information required about the distribution and abundance can be gathered through the application of various scientific census techniques. The assessment could be based on qualitative criteria on the occurrence such as present, absent, rare, common and abundant. However, it is often necessary to have information on abundance of population in terms of more quantitative measures like density. Some of the methods used in this respect in the case of tropical forests are briefly described here.

Total Count

Total count assumes that all the animals in a given area are counted by covering the entire area. This assumption does not hold good in most of the census operations especially in areas with inhospitable terrain and poor visibility. The problem becomes more complex while dealing with smaller and nocturnal animals. It would also be difficult to avoid double counting. In practice, total counts are made after identifying smaller units (Blocks) of the forest area based on natural/artificial boundaries. Teams of investigators cover these smaller units within given time and record the details of animals encountered. This method also assumes that all the areas in the units are covered and all the animals in the area are counted. In this method it is not possible to work out variance and confidence interval for the estimated population.

Sample Block Count Method

Sometimes, only a subset of the demarcated blocks are chosen following standard statistical survey design such as Simple Random Sampling, Stratified Random Sampling, etc. for counting the animals and the estimation is made to the total survey area and total number of animals worked out. In this method, estimation of variance and confidence limits for the total estimated population is possible unlike total count method. Such an approach is called as sample block count method. Although, in general, Block Count method is not identified as valid for estimation of abundance, valuable information can be obtained on population structure through this method.

Line transect sampling – Direct Sighting

Line transect sampling is one of the widely used scientific methods. If the method is applied properly, it provides a viable technique to determine point estimates and measures of variance of animal density. In line transect sampling, the observer(s) perform a standardized survey along a series of lines, searching for objects of interest (usually animals or cluster of animals). For each object detected, they record the perpendicular distance from the line to the object or radial distance from the observer to the object along with the angle of sighting. The main advantage with line transect sampling is that even without encountering all the animals in the area, it is possible to develop an estimate of the total number of animals or their density through appropriate statistical analyses. However, the method presupposes adequate sample size in terms of sightings without which precise estimate of density cannot be obtained by this method. Burnham *et al.* (1980) recommends a minimum of 40 sightings for satisfactory estimation of the detection function in the area.

Indirect Method

As mentioned earlier, it is often difficult to sight smaller animals and practically impossible to locate the nocturnal ones. Index of abundance or sometimes the actual density of such animals can be estimated by recording the number of indirect evidences such as hoof mark/droppings/pellets/dung of the animals in the given area. For the estimation of the density of indirect evidences, plots or line transects can be used. This method is comparatively simpler and yields a wealth of information on the abundance and distribution. However, this method requires skill in identification of indirect evidences of the species concerned. The density of indirect evidences can be converted into animal density using appropriate defecation and decay rate.

A number of factors affect the whole process of data collection in the field that would be reflected in the results. The climatic factors like unexpected rains could upset the spatial distribution of animals and wash away the indirect evidences and may inhibit the enthusiasm of the observers. Observers' experience as well as the possible aberration in the animal behaviour due to adverse climate could also contribute to the problems.

A general feature seen in many instances of wildlife census is the high Coefficient of Variation (CV) of the density estimates. This occurs mainly as a result of high variability in the occurrence of animal or indirect evidence among the sampling units. In

the case of line transect sampling, low number of sighting also leads to imprecise estimates. Increasing the sample size is one of the practical means of avoiding the problem. Generally, in wildlife census, estimates having CV larger than 20 per cent are considered not reliable.

Appendix II

Details of area devoid of elephants and water bodies accounted for calculating actual elephant habitat

Protected area/Forest Division	Total forest area as on 2005*	Area devoid of elephants (km ²)**	Water body **	Total area devoid of elephants	Actual elephant habitat#
Wayanad WLS	344.44	0	1.8	1.8	342.64
Aralam	55	0	0	0	55
Wayanad North	214.94	30.92	4.4	35.32	179.62
Wayanad South	347.5	25.82	6	31.82	315.68
Kannur	302.78	53.45	34.7	88.15	214.63
Kozhikode	290.22	0	9.8	9.8	280.42
Silent Valley NP	89.52	0	0	0	89.52
Mannarkad	529.56	20	6.9	26.9	502.66
Nilambur South	365.15	7.6	0	7.6	357.55
Nilambur North	398.64	19	1.1	20.1	378.54
Palakkad	235.57	33.31	25.5	58.81	176.76
Parambikulam WLS	274.14	0	22.9	22.9	251.24
Peechi WLS	126.73	35	15.7	50.7	76.03
Chimmony WLS	75	0	1.6	1.6	73.4
Idukki WLD	105.36	0	44.7	44.7	60.66
Thattekad BS	25.16	0	3.7	3.7	21.46
Eravikulam NP	97	0	0	0	97
Chinnar	90.44	0	0	0	90.44
Nenmara	355.96	26.8	10.3	37.1	318.86
Chalakkudi	279.71	15.68	0	15.68	264.03
Thrissur	210.01	210.01	0	210.01	0
Vazhachal	413.94	30	14.5	44.5	369.44
Munnar	730.19	0	0	0	730.19
Malayattur	617.77	50	46.7	96.7	521.07
Kothamangalam	317	17.35	2.9	20.25	296.75
Mankulam	90.06	0	0	0	90.06
Kottayam	692.15	302.47	29.3	331.77	360.38
Periyar Tiger Reserve	775	0	26	26	749
Ranni	1059.06	43.49	65.2	108.69	950.37
Konni	331.66	0	6	6	325.66
Achankovil	269	0	0	0	269
Punalur	280.22	229.86	4.4	234.26	45.96
Thenmala	131.17	8	2.5	10.5	120.67
Shendurney WLS	171	0	21.3	21.3	149.7
Thiruvananthapuram WLD	181	0	15.5	15.5	165.5
Thiruvananthapuram	368.6	40	5.3	45.3	323.3
ABP Special Division	31	0	0	0	31

* As per Kerala Forest Statistics-2005, Kerala Forest Department, Thiruvananthapuram ** As per the Elephant Census Report - 2005. # The grand total of the actual elephant habitat need not tally with Table 4.